SWRHL-30r

FINAL REPORT OF OFF-SITE SURVEILLANCE FOR THE NRX-A4/EST TEST SERIES

by the
Southwestern Radiological Health Laboratory
U. S. Public Health Service
Department of Health, Education, and Welfare
Las Vegas, Nevada

September 19, 1966

Copy No. 65

DTIE, USAEC

Oak Ridge, Tennessee

This surveillance performed under a Memorandum of Understanding (No. SF 54 373) for the U. S. ATOMIC ENERGY COMMISSION

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ABSTRACT

The Southwestern Radiological Health Laboratory provided off-site radiation surveillance for the NRX-A4/EST Project Rover Reactor test series which took place at NRDS test cell A. Of the six experimental plans in the test series, four resulted in detectable quantities of radioactivity in the off-site area as indicated below:

Experimental Plan	Date	Effluent Trajectory
2B	2/03/66	Northeast quadrant
3	3/03/66	Southerly at about 160°
4	3/16/66	Easterly at 82°
4A	3/25/66	Westerly at 265°

Although radioactive effluent was detected off-site from this event, the surveillance indicated that the radiation protection guides established by the Atomic Energy Commission (based on Federal Radiation Council guidelines), Chapter 0524, for the off-site population were not exceeded. The peak off-site potential thyroid exposure was about 36 millirad at Lone Pine, California.

TABLE OF CONTENTS

INTRODUCTION	1
OPERATIONAL PROCEDURES	4
A. EXTERNAL MEASUREMENTS	4
1. Ground Monitoring	4
2. Dose Rate Recorders	4
3. Aerial Cloud Tracking	5
4. Film Badges	5
5. Thermoluminescent Dosimeters (TLD)	5
B. ENVIRONMENTAL MEASUREMENTS	5
1. Milk and Water Samples	8
2. Vegetation Samples	8
RESULTS	9
A. EP-2B TEST, February 3, 1966	9
1. Ground Monitoring	9
2. Dose Rate Recorders	9
3. Film Badges and Thermoluminescent Dosimeters	9
4. Air Sampling	9
5. Milk Sampling	9
6. Vegetation Sampling	11
B. EP-2C TEST, February 11, 1966	11
1. Ground Monitoring	11
2. Dose Rate Recorders	16
3. Film Badges and Thermoluminescent Dosimeters	16
4. Air Sampling	16
5. Milk Sampling	16

Table of Contents (continued)

C. EP-3 TEST, March 3, 1966 16

1. Ground Monitoring 16

2. Dose Rate Recorders 18

3. Film Badges and Thermoluminescent Dosimeters 18

4. Air Sampling 19

5. Milk Sampling 19

D. EP-4 TEST, March 16, 1966 19

1. Ground Monitoring 19

2. Dose Rate Recorders 19

3. Film Badges and Thermoluminescent Dosimeters 19

4. Air Sampling 22

5. Milk Sampling 22

6. Vegetation Sampling 24

E. EP-4A TEST, March 25, 1966 24

1. Ground Monitoring 24

2. Dose Rate Recorders 24

3. Film Badges and Thermoluminescent Dosimeters 26

4. Air Sampling 26

5. Milk Sampling 26

6. Vegetation Sampling 30

7. Thyroid *In Vivo* Counting 30

8. Water 30

CONCLUSIONS 34

APPENDIX I - Thyroid Dose

DISTRIBUTION

LIST OF TABLES

Table 1.	NRX-A4/EST test series data.	1
Table 2.	Threshold detectability at time of count of several radionuclides in air samples (90% confidence level).	7
Table 3.	Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-2B.	11
Table 4.	Analyses of air samples collected following NRX-A4/EST EP-2B.	12
Table 5.	Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-2C.	14
Table 6.	Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-3.	18
Table 7.	Analyses of air samples collected following EP-3.	20
Table 8.	Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-4.	22
Table 9.	Analyses of air samples collected following EP-4.	23
Table 10.	Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-4A.	25
Table 11.	Analyses of air samples collected following EP-4A.	28
Table 12.	Analysis of milk samples collected following EP-4A.	29
Table 13.	Water Results - NRX-A4/EST EP-4A.	33
Table 14.	Peak gamma doses detected off the test range complex for NRX-A4/EST.	34
Table 15.	Peak iodine concentrations as measured by air samplers.	35
Table 16.	Estimates of thyroid exposures from peak iodine concentrations.	35

LIST OF FIGURES

Figure 1.	Hot line locations following NRX-A4/EST Experiments.	3
Figure 2.	Sampling locations following NRX-A4/EST EP-2B.	10
Figure 3.	Sampling locations following NRX-A4/EST EP-2C.	13
Figure 4.	Sampling locations following NRX-A4/EST EP-3.	17
Figure 5.	Sampling locations following NRX-A4/EST EP-4.	21
Figure 6.	Sampling locations following NRX-A4/EST EP-4A.	27
Figure 7.	Iodine-131 in milk, Lone Pine, Calif., following NRX-A4/EST, 3/25/66, EP-4A.	31
Figure 8.	Natural vegetation samples along Highway 95.	32

INTRODUCTION

As a part of the Rover Program, testing and disassembling of a series of reactors designated NRX is being conducted at the Nuclear Rocket Development Station (NRDS) under the auspices of the NERVA program. The subject of this report is the off-site radiological surveillance provided by the Public Health Service (PHS) for the Atomic Energy Commission (AEC) in support of the EP-2B, EP-2C, EP-3, EP-4 and EP-4A experiments of the NRX-A4/EST test series.

Under a memorandum of understanding with the Atomic Energy Commission, the U. S. Public Health Service conducts a program of radiological monitoring and environmental sampling in the off-site area surrounding the Nevada Test Site and the Nellis Air Force Range (NAFR), which includes the Nuclear Rocket Development Station and the Tonopah Test Range. For simplicity this area will be called the test range complex throughout this report.

The following table lists the operating times and integral powers of each of the experiments covered in this report.

Table 1. NRX-A4/EST test series data.

Experiment	Date	Time of Operation PST	Mw-sec	Radiation Detectable Off-Site
EP-2B	2/03/66	1116-1123 1459-1510	3.9×10^5	Yes
EP-2C	2/11/66	1220-1230 1422-1443	4.3×10^5	No
EP-3	3/03/66	1310-1316 1550-1605	8.7×10^5	Yes
EP-4	3/16/66	1004-1020	1.0×10^6	Yes
EP-4A	3/25/66	0933-0948	1.05×10^6	Yes

All of the above experiments were conducted at Test Cell A. The reactor was tested in an upright position so that the hydrogen coolant exhausted upward along with escaping fission products. The "hot lines" as estimated from ground sampling are presented in Figure 1. The effluent from EP-2C was not detected off-site and is thus not shown in Figure 1. The effluent eventually moved in a south to southeast direction from the test cell.

Figure 1. Hot line locations following NRX-A4/EST Experiments.

OPERATIONAL PROCEDURES

A. EXTERNAL MEASUREMENTS

1. Ground Monitoring

Ground monitors tracked the reactor effluent passage with portable instruments. Each monitor was equipped with an Eberline E-500B, a Precision Model 111 Standard "Scintillator", and a Victoreen Radector Model No. AGB-50B-SR.

The Eberline E-500B has a range of 0 to 200 milliroentgens per hour (mR/hr) beta-gamma detection in four scales with an external halogen filled GM tube and a 0 to 2000 mR/hr range, gamma only, from an internal Anton 302 tube. The Precision Model 111 "Scintillator" is used primarily for low level detection and provides for a range of 0 to 5 mR/hr in six scales. The Radector has a range of 0.05 to 50,000 mR/hr on two scales. This instrument employs an inert gas ionization chamber. Errors associated with these instruments are of the order of $\pm$20% as calibrated with ^{137}Cs.

2. Dose Rate Recorders

Eberline RM-11 Dose Rate Recorders are placed at twenty-two stations around the test range complex. These recorders utilize a Geiger-Mueller tube detector to document radiation levels at specific locations. The instrument has a 0.01 to 100 mR/hr range and the gamma dose rate is recorded on a 30-hour strip chart. The RM-11 is accurate to $\pm$20% as calibrated with a cesium-137 source.

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963

3. Aerial Cloud Tracking

An Air Force U3-A aircraft, manned by two Public Health Service monitors equipped with portable instruments identical to those of the ground monitors, tracked the reactor effluent to position ground monitors. Public Health Service cloud sampling aircraft were also used as aids in cloud tracking, however their primary purpose was cloud sampling in order to determine cloud size and inventory. The results of their sampling are reported separately by the SWRHL Engineering Development Program.

4. Film Badges

The experiments took place during the months of February and March. The PHS maintained approximately 74 film badge stations off the test range complex and assigned badges to 144 off-site residents during February, and maintained 77 film badge stations and assigned badges to 132 off-site residents during March. The badge used is made of Du Pont type 555 film. This film is accurate to $\pm$50% in the 20 to 100 mR range and $\pm$10% in the 100 to 2000 mR range. The lower limit of detectability is 20 mR.

5. Thermoluminescent Dosimeters (TLD)

Approximately 20 TLD's per month were used in the off-site surveillance program. The TLD's are used with read-out equipment manufactured by Edgerton, Germeshausen and Grier, Inc., and have a lower detection limit of about 5 mR.

B. ENVIRONMENTAL MEASUREMENTS

One hundred and seven air samplers were routinely operated by the Air Surveillance Network (ASN) in the western United States at the time of these experiments. The air sampler used by the ASN is a

Gelman "Tempest." The "Tempest" employs a Gast Model 1550 vacuum pump driven by a General Electric 1/2 horsepower motor. The pump runs at 1440 rpm and draws an average flow rate of 10 cfm. During the time of these experiments, wider coverage was being developed in the states of California, Utah and Nevada. Thirty-nine air samplers were located in Nevada. Supplementary temporary air sampler locations were established as deemed necessary to cover cloud passage. All samplers were equipped with Whatman 541 prefilters which have a pore size of 3 - 4 microns. A portion of the routine samplers and all supplementary stations were equipped with MSA Part 46727 charcoal cartridges. This is the chemical cartridge for organic vapors and is impregnated with stable elemental and sodium iodine and should have a fair efficiency for methyl iodine. All air sample prefilters and charcoal cartridges collected following the NRX/EST series were returned to the Southwestern Radiological Health Laboratory in Las Vegas for analysis.

Prefilters were counted for gross beta activity in a Beckman "Wide Beta" low background (6 ± 1 cpm beta) proportional system which has an efficiency of approximately 45% for 0.54 Mev betas. After an initial count, if no significant activity is detected, the filters are counted at five and twelve days after collection. In all other cases, filters are recounted a minimum of three times in the first 48 hours following collection. The computational procedure employed depends upon the assumption that a decay constant can be determined for each individual sample and that this constant can then be used to extrapolate the activity to the end of the collection period. For this purpose the general decay equation $A/A_o = e^{-\lambda t}$ is employed.

Filter papers and charcoal cartridges were analyzed for gamma isotopes by placing them directly on a 4" x 4" NaI(Tl) crystal coupled to a TMC Model 404C gamma pulse height analyzer viewing energies from 0 to 2 Mev. Since it was not possible to define duration of cloud passage at all locations, reported values given as pCi-sec/m^3 represent the integrated air concentration. This value is obtained as follows:

$$\frac{\text{(activity in pCi) (sampling time in seconds)}}{\text{sample volume in } m^3} = \text{integrated air concentration (pCi-sec/}m^3\text{)}.$$

Threshold detectability of several radionuclides is presented in Table 2 and is the result of an examination of previous data collected under the following conditions:

a. Count time in days after fissioning as indicated by footnotes.

b. Prefilters collect unfractionated fission products resulting in a complex spectrum.

c. MSA charcoal collects gaseous fission products only (primarily iodines).

d. An eight isotope matrix is employed for computation and isotopes other than those examined are present in amounts which are small relative to those eight.

e. Natural activity on air samples is approximately five times system background.

Table 2. Threshold detectability at time of count of several radionuclides in air samples (90% confidence level).

Sample type	-pCi-					Length of count	Notes
	^{131}I	^{132}Te-I	^{133}I	^{135}I	^{140}Ba-La		
Whatman No. 541	500	1000	500	1000	500	10 min	1
	200	-	200	-	200	10 min	2
MSA Charcoal	200	400	200	400	200	10 min	1
	100	-	100	-	100	10 min	2

1 - counted at less than 3 days after fissioning.
2 - counted at 3 days or more after fissioning.

1. **Milk and Water Samples**

After the release of activity from NRDS, milk samples were collected from dairy farms and farms producing milk for their own consumption which were believed to have been in the cloud path. Each milk sample is counted for 40 minutes using a 400-channel analyzer viewing an energy range from 0 to 2 Mev. All liquid samples are counted in 3.5 liter inverted well aluminum beakers which are placed over a 4"x4" sodium iodide crystal. The lower limit of detection for ^{131}I and ^{133}I in milk and water is 20 pCi/l at time of count, and all results below that value are reported as non-detectable. The reported values have, at time of count, a 2 sigma error estimate of $\pm$ 15 pCi/l or $\pm$ 10%, whichever is greater.

2. **Vegetation Samples**

Vegetation samples were collected in the suspected effluent trajectory to indicate deposition on the ground. They were also obtained at most milk sampling locations, with an effort made to make the sample representative of the cows' feed. These samples were taken as early indicators of where milk might be contaminated and were not intended to yield intake-excretion data. For this reason the vegetation sample results are reported simply as fresh fission products present or not present.

RESULTS

A. EP-2B TEST, February 3, 1966

A summary of the meteorological conditions on the test day is presented in Table 3. Due to the wind shear which existed on the test day, environmental samples, e.g. vegetation, air and milk were obtained from an azimuth of 270° to 45°. Sample locations are shown in Figure 2.

1. Ground Monitoring

   There were no detectable dose rates in the off-site area as measured by ground monitors.

2. Dose Rate Recorders

   There were no detectable dose rates in the off-site area as measured by remote dose rate recorders.

3. Film Badges and Thermoluminescent Dosimeters(TLD's)

   Film badges and TLD's exposed during February indicated no doses above the detection limit (20 mR and 5 mR respectively) that could be attributed to EP-2B effluent.

4. Air Sampling

   The air sampler prefilters obtained from Twin Springs Ranch, Diablo and Hiko, Nevada, contained less than 0.2 pCi/m^3 ^{133}I. These were the only air samples that contained fresh fission products.

   A summary of the air data is presented in Table 4.

5. Milk Sampling

   Milk was sampled at four different locations following EP-2B, as shown in Figure 2. None of the samples contained radioiodine.

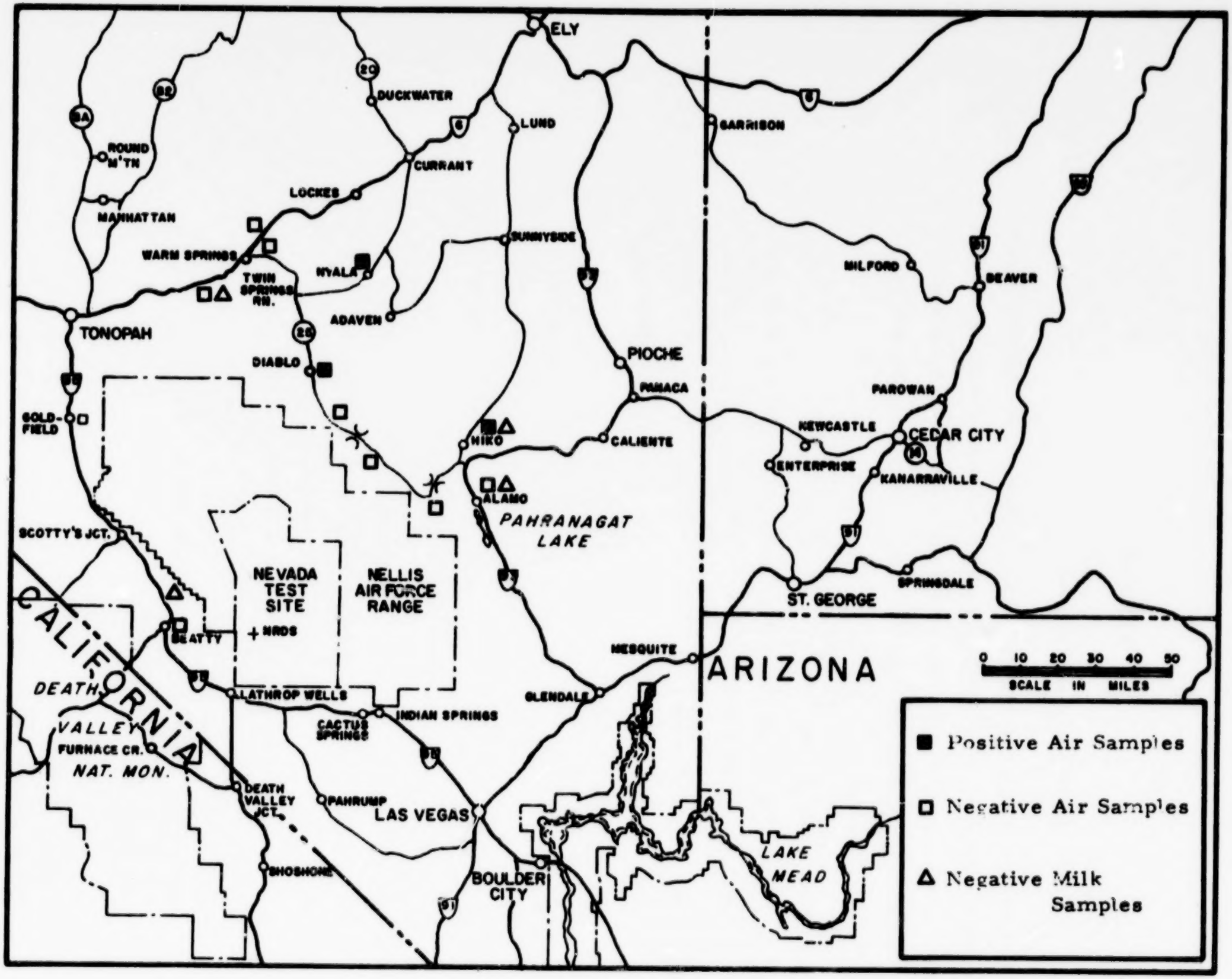

Figure 2. Sampling locations following NRX-A4/EST EP-2B.

6. Vegetation Sampling

Vegetation samples collected following EP-2B contained no activity above background levels.

Table 3. Meteorological data supplied by the Environmental Science Serivce Agency for NRX-A4/EST EP-2B.

Sky condition : clear
Visibility : unrestricted
Upper air data at: Jackass Flats, Nevada 1000 PST 2/03/66

Height (Ft. MSL)	Wind (Deg/Kts)	Pressure (mb)	Temperature (^{o}C)	Dew Point (^{o}C)	Relative Humidity (%)
SFC 3,615	110/13	900	8.8	- 6.1	37
4,000	090/11	887	6.0	- 9.1	33
5,000	100/12	854	4.0	-12.0	30
6,000	170/08	822	2.2	-14.5	28
7,000	180/13	792	0.3	-16.9	26
8,000	190/18	762	-1.5	-19.4	24
9,000	200/22	734	-2.8	-22.7	20
10,000	220/20	706	-1.9	-23.7	17
11,000	220/17	679	-1.9	-22.5	19
12,000	220/17	653	-2.8	-16.2	35
13,000	220/20	629	-4.8	-16.4	40
14,000	220/23	605	-7.1	-18.4	40
15,000	230/20	581	-9.6	-20.7	40

SFC - Surface

B. EP-2C TEST, February 11, 1966

Environmental samples (air, milk and vegetation) following EP-2C did not contain fresh fission products. Sample locations are shown in Figure 3. Ground monitoring and dose rate recorders also yielded no positive measurements. Meteorological observations on the test day are presented in Table 5.

1. Ground Monitoring

As a result of aerial cloud tracking information, ground monitoring was performed south of NRDS following the first

Table 4. Analyses of air samples collected following NRX-A4/EST EP-2B, February 3, 1966.

Location	Air Volume (m^3)	Date Time On	Date Time Off	Gross Beta Activity Prefilter at end of collection (pCi/m^3)	$\frac{pCi\text{-}sec^*}{m^3} \times 10^{-3}$	Collector	Gamma pulse height analysis Activity (pCi/m^3) at end of collection ^{131}I	^{132}I	^{133}I	^{135}I
Hwy. Maint. Stn., Diablo, Nevada	475	2-3 0700	2-4 0700	.053	4.5	P	ND	ND	0.17	ND
						C	ND	ND	ND	ND
Hiko, Nevada	497	2-3 0800	2-4 0800	.026	2.2	P	ND	ND	0.18	ND
						C	ND	ND	ND	ND
Twin Springs Rn. Warm Springs, Nev.	452	2-3 1030	2-4 0930	.063	4.8	P	ND	ND	0.16	ND
						C	ND	ND	ND	ND

ND - not detectable
P - prefilter
C - charcoal cartridge
* - the time shown on the running time meter is used in calculating $\frac{pCi\text{-}sec}{m^3}$ rather than the time on and time off reported by the station operator. This is done because the two do not always agree due to power failures, etc.

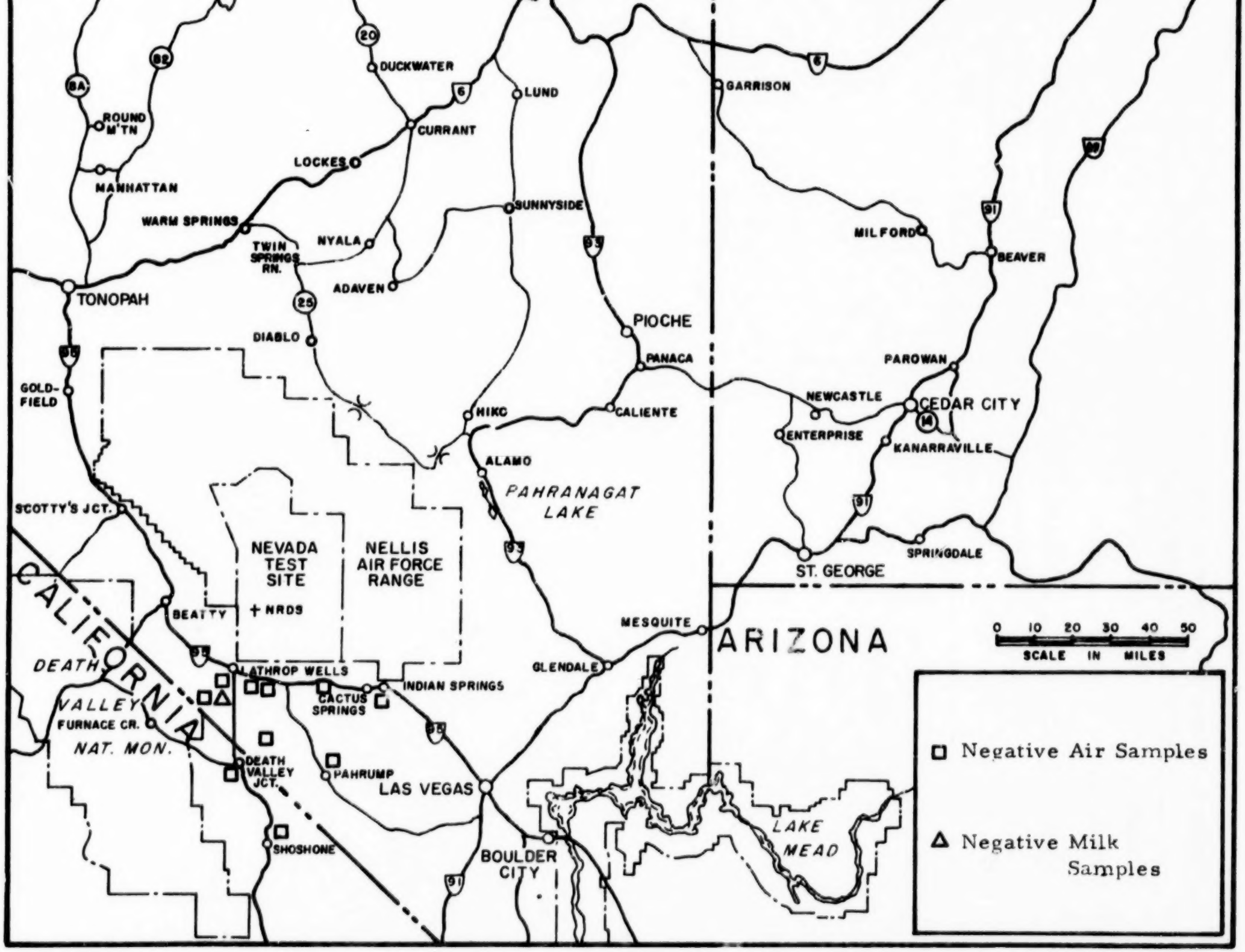

Figure 3. Sampling locations following NRX-A4/EST EP-2C.

Table 5. Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-2C.

Clouds : 0.4 altocumulus, 0.5 cirrus

Visibility : unrestricted

Upper air data at: Jackass Flats, Nevada 1000 PST 2/11/66

Height (Ft. MSL)	Wind (Deg/Kts)	Pressure (mb)	Temperature (°C)	Dew Point (°C)	Relative Humidity (%)
SFC 3,615	090/08	900	3.7	- 4.0	56
4,000	000/00	888	2.5	- 7.1	49
5,000	080/02	853	- 1.9	-19.3	25
6,000	020/06	820	- 2.6	-20.9	23
7,000	030/12	794	- 1.6	-21.6	20
8,000	040/15	759	- 2.8	-23.9	18
9,000	030/15	730	- 4.4	-25.12	18
10,085	030/17	700	- 6.2	-26.7	18
11,000	010/19	674	- 7.9	-28.2	18
12,000	020/27	646	- 9.5	-29.0	19
13,000	360/28	622	-10.8	-28.5	22
14,000	010/27	597	-12.0	-28.5	24
15,000	010/32	574	-13.3	-28.4	27

SFC - surface

Table 5. Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-2C(continued)

Clouds : 0.3 cirrus

Visibility : unrestricted

Upper air data at: Jackass Flats, Nevada 1615 PST 2/11/66

Height (Ft. MSL)	Wind (Deg/Kts)	Pressure (mb)	Temperature (^{o}C)	Dew Point (^{o}C)	Relative Humidity (%)
SFC 3,615	240/04	896	8.9	-15.6	16
4,000	230/05	884	7.0	-15.7	18
5,000	248/04	850	3.8	-16.6	21
6,000	325/04	820	1.0	-18.3	22
7,000	356/06	788	0.3	-20.6	19
8,000	348/09	760	- 1.1	-22.5	18
9,000	327/08	730	- 2.8	-23.9	18
10,000	323/18	704	- 4.3	-25.8	17
11,000	323/18	676	- 4.9	-23.5	22
12,000	330/19	650	- 6.6	-21.5	30
13,000	336/18	625	- 8.8	-21.0	37
14,000	336/29	600	-11.0	-20.9	44
14,200	340/29	596	-11.4	-20.7	46
15,000	331/28	577	-11.1	-21.5	42

SFC - surface

segment of EP-2C. The second segment of EP-2C resulted in a split cloud with one section headed towards the northeast and the other towards the south. It was predicted that the cloud towards the northeast would eventually move towards the southeast and thus sampling was performed along Hwy. 95. All ground monitoring was negative.

2. Dose Rate Recorders

   No increase in activity above background was indicated on recorders including those from Pahrump, Lathrop Wells, and Indian Springs, Nevada.

3. Film Badges and Thermoluminescent Dosimeters

   Film badges and TLD's exposed during February indicated no doses above the detection limit (20 mR and 5 mR respectively) that could be attributed to EP-2C effluent.

4. Air Sampling

   As a result of aerial cloud tracking information, air samples were collected southeast of NRDS. No air samples were found to contain fresh fission products.

5. Milk Sampling

   A milk and feed sample collected from Dansby Ranch near Lathrop Wells, Nevada did not contain fresh fission products.

C. EP-3 TEST, March 3, 1966

A summary of meteorological conditions on the EP-3 test day is presented in Table 6. Environmental sampling locations (air and milk) are shown in Figure 4.

1. Ground Monitoring

   As a result of aerial cloud tracking, ground monitoring was

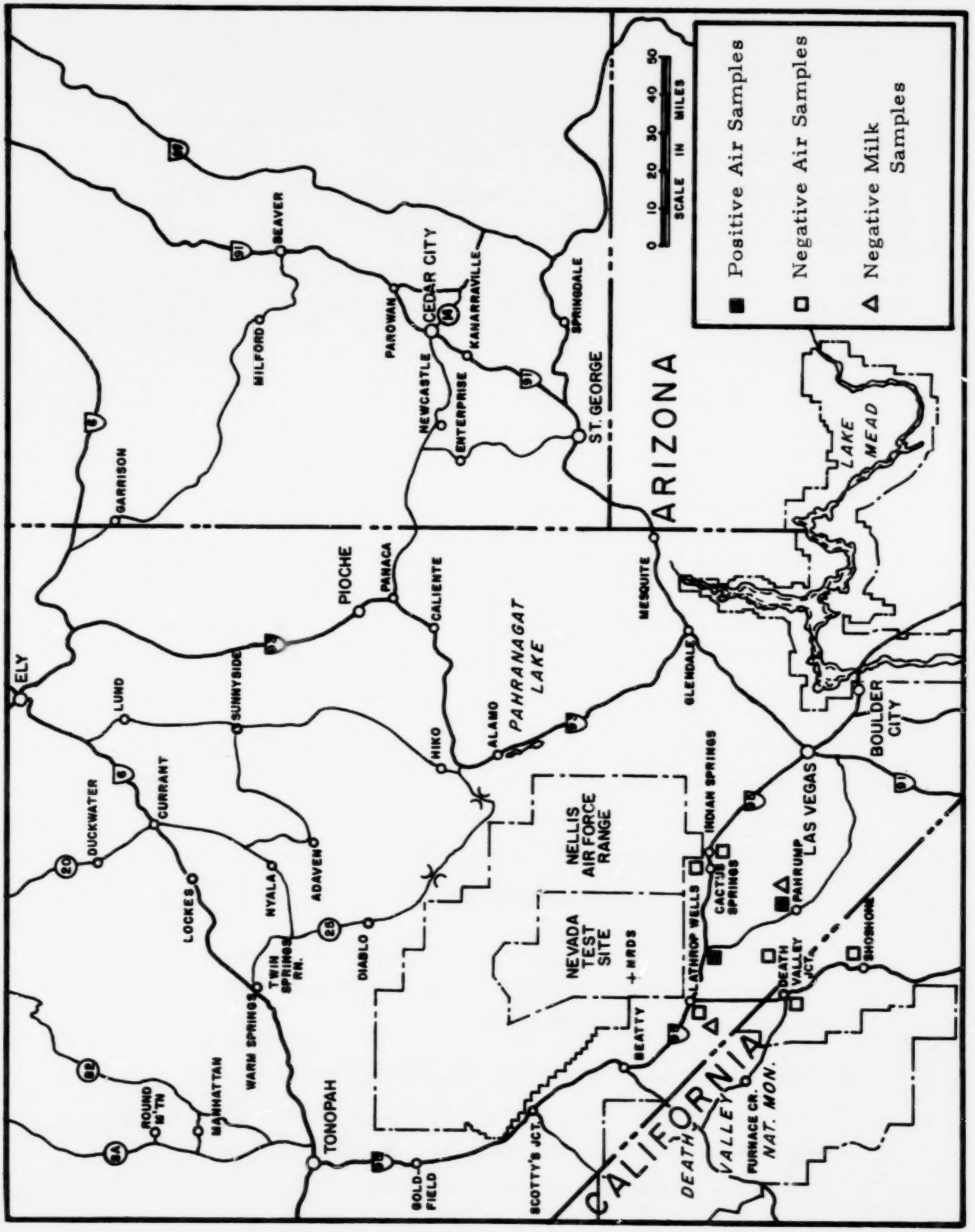

Figure 4. Sampling locations following NRX-A4/EST EP-3.

Table 6. Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-3.

Sky condition : 2/10
Clouds : Cumulus
Visibility : unrestricted
Upper air data at: Jackass Flats, Nevada 1325 PST 3/3/66

Height (Ft. MSL)	Wind (Deg/Kts)	Pressure (mb)	Temperature (^{o}C)	Dew Point (^{o}C)	Relative Humidity (%)
SFC 3,615	030/06	894	5.6	-10.6	30
4,000	020/06	882	3.5	-11.6	32
5,000	360/08	849	0.7	-13.8	33
6,000	340/11	815	- 2.2	-16.3	33
7,000	330/13	784	- 5.2	-18.3	35
8,000	320/14	754	- 7.9	-20.4	36
9,000	320/12	726	-10.7	-22.5	37
10,000	330/11	697	-13.9	-24.7	40
11,000	340/11	666	-17.1	-26.7	43
12,000	350/08	638	-19.6	-29.7	40
13,000	330/04	610	-21.8	-32.6	37
14,000	330/41	584	-19.0	-32.3	30
15,000	330/69	559	-19.4	-33.0	29

SFC - surface

performed along the eastern side of the Amargosa Valley along a hot line of 160^{o}. A monitor on Hwy. 95 located 17 miles ESE of Lathrop Wells, measured intensities of less than 0.01 mR/hr above background during the interval of 1505 to 1540 hours PST. Positive dose rates were not measured at other monitored locations.

2. Dose Rate Recorders

No increase in activity above background was indicated on any of the dose rate recorders.

3. Film Badges and Thermoluminescent Dosimeters

Film badges and TLD's exposed during March indicated no doses above the detection limit (20 mR and 5 mR respectively) that could be attributed to EP-3 effluent.

4. Air Sampling

Air samples from two locations contained ^{133}I on the pre-filters and cartridges. A summary of the air data is presented in Table 7.

5. Milk Sampling

Milk and feed samples were obtained from those locations shown in Figure 4 following the EP-3 test. The samples indicated no activity above background levels.

D. EP-4 TEST, March 16, 1966

The EP-4 Test resulted in detectable levels of radioactivity in the off-site area. Meteorological conditions on the test day are presented in Table 8. Environmental sampling locations (air and milk) are shown in Figure 5.

1. Ground Monitoring

Highway 93 was monitored between Glendale and Alamo during the approximate time of cloud passage. Levels of less than 0.03 mR/hr above background were detected from 36 miles NE of Glendale to Alamo.

2. Dose Rate Recorders

Dose rate recorders at Warm Springs Ranch, Caliente, Alamo, Pioche and St. George did not indicate dose rates on March 16 and 17 above the local background levels (<0.02 mR/hr).

3. Film Badges and Thermoluminescent Dosimeters

Film badges and TLD's exposed during March indicated no doses above the detection limit (20 mR and 5 mR respectively) that could be attributed to EP-4 effluent.

Table 7. Analyses of air samples collected following EP-3.

Location	Air Volume (m^3)	Date Time On	Date Time Off	Gross Beta Activity Prefilter at end of collection (pCi/m^3)	Gross Beta Activity Prefilter at end of collection $\frac{pCi\text{-}sec}{m^3} \times 10^{-3}$	Col-lec-tor	Gamma pulse height analysis Activity (pCi/m^3) at end of collection ^{131}I	^{132}I	^{133}I	^{135}I
Ash Meadows, Nevada Jct. Ash Meadows Rd and U S 95	195	3-3 1300	3-4 0720	1.6	106	P	ND	ND	2.2	ND
						C	ND	ND	2.0	ND
Pahrump, Nevada	479	3-3 1046	3-4 1030	.75	64	P	ND	ND	0.57	ND
						C	ND	ND	0.79	ND

ND - not detectable
P - prefilter
C - charcoal cartridge

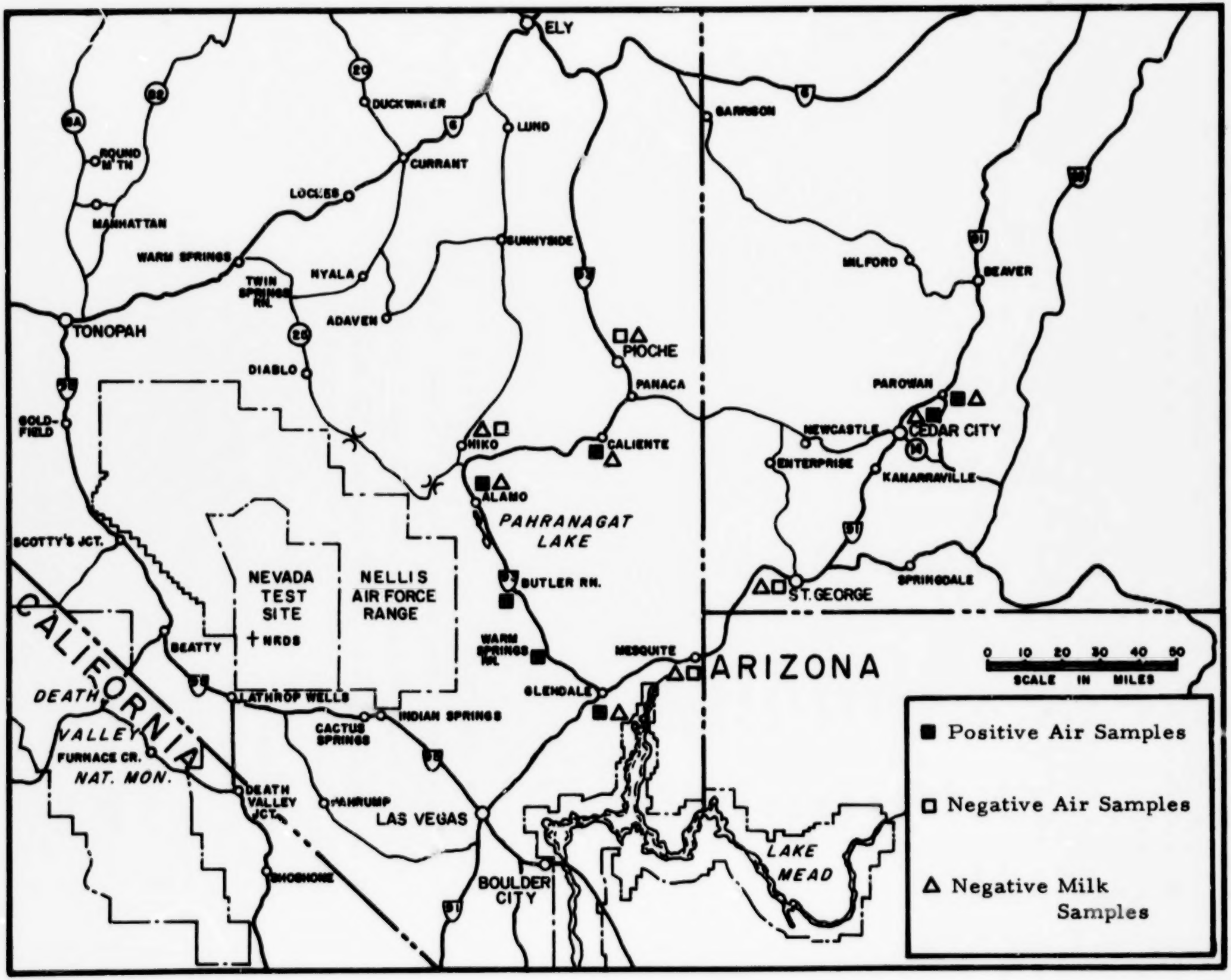

Figure 5. Sampling locations following NRX-A4/EST EP-4.

Table 8. Meteorological data supplied by the Environmental Science Service Agency for NRX-A4/EST EP-4.

Sky condition : 14,000 Sctd., high thin broken
Clouds : 0.4 altocumulus, 0.6 cirrostratus
Visibility : unrestricted
Upper air data at: Jackass Flats, Nevada, 1005 PST, 3/16/66

Height (Ft. MSL)	Wind (Deg/Kts)	Pressure (mb)	Temperature (°C)	Dew Point (°C)	Relative Humidity (%)
SFC 3,615	240/10	889	15.2	- 5.8	23
4,000	230/10	879	12.5	- 6.5	26
5,000	200/09	850	9.5	- 7.6	29
6,000	210/10	815	6.5	- 9.4	31
7,000	270/10	785	5.9	-10.8	29
8,000	300/15	755	3.4	-13.4	28
9,000	290/17	728	0.9	-16.0	27
10,039	280/14	700	- 2.0	-18.9	26
11,000	270/18	674	- 4.5	-21.1	26
12,000	270/25	649	- 5.6	-24.0	22
13,000	270/33	624	- 7.5	-26.6	20
14,006	280/45	600	- 9.4	-28.8	19
15,000	280/51	576	-11.0	-29.6	20

SFC - surface

4. Air Sampling

Samples containing radioiodines were obtained from Alamo, Butler Ranch turnoff and Highway 93, Warm Springs Ranch, Glendale and Caliente, Nevada, and Cedar City and Parowan, Utah. Negative samples were obtained at other locations as shown in Figure 5. Table 9 presents the results of air filter analyses.

5. Milk Sampling

Milk and feed samples were obtained in the area of the effluent path on March 17, at locations shown in Figure 5. All results were negative. At all sampled locations the animals were not yet on pasture.

Table 9. Analyses of air samples collected following EP-4.

Location	Air Volume (m^3)	Date Time On	Date Time Off	Gross Beta Activity Prefilter at end of collection. (pCi/m^3)	Gross Beta Activity Prefilter at end of collection. $\frac{pCi\text{-}sec}{m^3} \times 10^{-2}$	Collector	Gamma pulse height analysis Activity (pCi/m^3) at end of collection. ^{131}I	^{132}I	^{133}I	^{135}I
Alamo, Nevada	489	3-16 0750	3-17 0800	0.64	560	P	0.35	ND	0.82	ND
						C	--	--	--	--
Butler Ranch turnoff and Hwy 93, Nevada	20	3-16 1350	3-16 1600	110	8700	P	25	75	24	ND
						C	ND	ND	6.1	7.9
Glendale Jct., Nevada	96	3-16 1230	3-16 1718	74	13000	P	2.4	4.6	.73	9.6
						C	1.6	1.2	1.7	1.7
Caliente, Nevada	348	3-16 1600	3-17 0835	0.79	470	P	0.57	1.6	1.2	0.91
						C	0.58	0.47	0.98	ND
Warm Springs Rn., Nev	502	3-16 0800	3-17 1010	0.26	250	P	0.21	0.42	0.34	ND
						C	ND	ND	ND	ND
Cedar City, Utah	372	3-16 1515	3-17 1250	0.36	270	P	0.30	ND	0.35	ND
						C	0.37	ND	0.85	ND
Parowan, Utah	448	3-15 2230	3-16 2230	0.25	220	P	0.18	ND	0.41	ND
						C	--	--	--	--

ND - not detectable
P - prefilter
C - charcoal cartridge
-- - sample not obtained

6. Vegetation Sampling

An experiment to compare fallout trays versus vegetation samples was conducted by PHS on the Nevada Test Site. The results from both clearly indicated a hot line of 82° at a distance of 14 miles from Test Cell A, or 6 miles south of CP-1 on the Mercury Highway.

E. EP-4A TEST, March 25, 1966

Radioactivity was detected off-site following the EP-4A Test. Meteorological conditions on the test day are presented in Table 10.

1. Ground Monitoring

Monitors located on Highway 95 detected cloud passage with survey instruments. Monitoring was performed along highways in a south-southwesterly quadrant from the test site. A monitor located 14 miles SE of Beatty, along Highway 95, detected an external gamma dose of 2.7 mR (integrated exposure from E-500B) due to cloud passage. The infinite dose at this unpopulated location is estimated to be 17 mR. Ground monitors were able to locate activity (<0.03 net mR/hr) in the area between Lone Pine, California and Stovepipe Wells.

2. Dose Rate Recorders

The RM-11 dose rate recorder at Beatty, Nevada, indicated a dose rate of up to 0.02 mR/hr above background between 1330 and 1830 hours on March 25. A dose of 0.05 mR above background was calculated by integration of the dose rate with time. The other recorders did not show a significant exposure above background.

Table 10. Meteorological data supplied by Environmental Science Service Agency for NRX-A4/EST EP-4A

Sky condition : 7000' Sctd., High Sctd.

Clouds : 0.4 Stratocumulus, 0.1 Cirrostratus

Visibility : unrestricted

Upper air data at: Jackass Flats, Nevada 0940 PST 3/25/66

Height (Ft. MSL)	Wind (Deg/Kts)	Pressure (mb)	Temperature (^{o}C)	Dew Point (^{o}C)	Relative Humidity (%)
SFC 3,615	100/08	889	17.8	- 2.5	25
4,000	100/08	875	16.0	- 4.6	24
5,000	100/09	847	12.4	- 6.1	27
6,000	080/07	816	9.1	- 6.7	32
7,000	070/09	785	6.2	- 8.1	35
8,000	080/10	756	3.3	- 9.0	40
9,000	080/11	729	0.3	-10.5	44
10,000	080/13	703	- 2.2	-11.5	49
11,000	080/15	674	- 5.7	-11.0	66
12,000	080/21	649	- 7.6	-14.9	56
13,000	080/24	622	- 9.4	-16.5	56
14,000	090/26	599	-11.3	-21.5	43
15,000	080/33	575	-13.0	-26.6	31

SFC - surface

3. Film Badges and Themoluminescent Dosimeters

Film badges and TLD's exposed during March indicated no doses above the detection limit (20 mR and 5 mR respectively) that could be attributed to EP-4A effluent.

4. Air Sampling

Samples containing fresh fission products were obtained at several locations. All sampled locations are shown in Figure 6. The peak concentrations in air were detected at Lone Pine, California where it is estimated the potential thyroid exposure was 3.6 mR, primarily due to inhalation of ^{131}I and ^{133}I. This assumes that all the ^{131}I and ^{133}I as collected on the prefilter and charcoal cartridge are biologically available for thyroid uptake from inhalation. A summary of the air sampling data is presented in Table 11.

5. Milk Sampling

Milk and feed samples were obtained at several locations in California and Nevada as indicated in Figure 6. Radioiodine was detected in milk from Lone Pine, Independence, and Big Pine, California. The peak concentration was 140 pCi of ^{131}I/liter and 230 pCi of ^{133}I/liter; this occurred in Lone Pine milk collected from the evening milking on March 27. Milk sampling results are presented in Table 12. The potential thyroid dose to an infant's thyroid from ^{131}I ingestion at Lone Pine is estimated to be 22 millirad. The ^{133}I ingestion dose is estimated to be 3 mrad. The cows' feed at the three locations was primarily made up of dry feed (hay), and less than 10% of the total intake was grass. A plot of the radioiodine concentrations in milk is presented

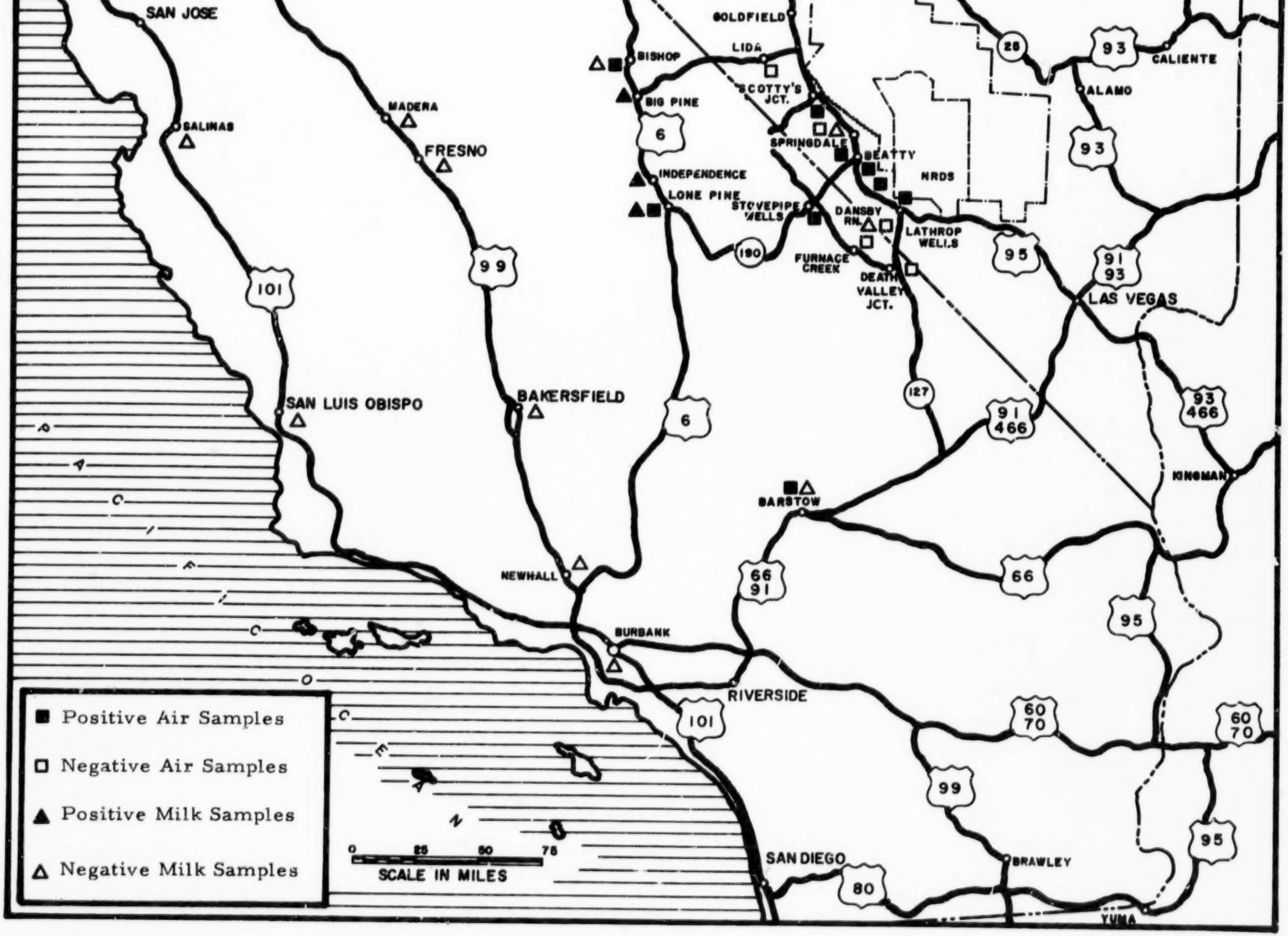

Figure 6. Sampling locations following NRX-A4/EST EP-4A.

Table 11. Analyses of air samples collected following EP-4A.

Location	Air Volume (m^3)	Date Time On	Date Time Off	Gross Beta Activity Prefilter at end of collection (pCi/m^3)	Gross Beta Activity Prefilter at end of collection $\frac{pCi\text{-}sec}{m^3} \times 10^{-3}$	Col-lec-tor	Gamma pulse height analysis Activity (pCi/m^3) at end of collection ^{131}I	^{132}I	^{133}I	^{135}I
Beatty, Nevada	442	3-25 0753	3-26 0733	17	1,400	P	ND	ND	0.87	ND
						C	1.2	ND	ND	ND
Hwy. 95, 15 mi NW of Lathrop Wells, Nev.	34	3-25 1130	3-25 1545	64	990	P	ND	ND	5.6	ND
						C	ND	6.1	16	1.6
Hwy. 95, 25 mi NW of Lathrop Wells, Nev.	48	3-25 1055	3-25 1540	140	2,400	P	ND	ND	7.9	ND
						C	ND	6.0	11	23
Lathrop Wells, Nev.	473	3-25 0640	3-26 0605	7.1	600	P	1.9	ND	ND	ND
						C	ND	ND	0.56	0.63
Scotty's Jct., Nev.	299	3-25 1705	3-26 0905	29	1,700	P	ND	ND	1.5	ND
						C	ND	ND	0.56	ND
Stovepipe Wells, Calif.	386	3-25 1140	3-26 0930	31	2,400	P	6.7	ND	ND	ND
						C	2.4	1.2	6.8	3.0
Lone Pine, Calif.	432	3-25 0948	3-26 0940	650	56,000	P	61	ND	70	ND
						C	25	12	74	ND
Bishop, Calif.	398	3-25 1010	3-26 0624	6.7	490	P	ND	ND	0.86	ND
						C	ND	ND	ND	ND
Barstow, Calif.	546	3-25 0700	3-26 1315	4.7	510	P	ND	ND	0.50	ND
						C	ND	ND	ND	ND

ND - not detectable
P - prefilter
C - charcoal cartridge

Table 12. Analysis of milk samples collected following EP-4A.

Location	Date Collected	Presence of Radioiodine in feed.	Gamma pulse height analysis (pCi/liter) ^{131}I	^{133}I
Lone Pine, Calif.	3/26-am	x	ND	50
	3/27-am	x	110	180
	3/27-pm	--	140	230
	3/28-am	x	100	70
	3/28-pm	x	100	40
	3/29-am	x	60	ND
	3/29-pm	x	90	30
	3/30-pm	x	70	ND
	3/31-am	x	50	ND
	3/31-pm	x	90	ND
	4/01-am	x	60	ND
	4/02-am	--	50	ND
	4/03-am	--	50	ND
	4/04-am	x	30	ND
	4/11-am	ND	ND	ND
Independence, California Zucco Ranch	3/29-pm	x	ND	ND
	3/30	x	--	--
	3/31-am	x	20	ND
	4/01-am	ND	ND	ND
Big Pine, Calif.	3/26-am	x	ND	ND
	3/27	x	--	--
	3/28-am	ND	ND	ND
	3/28-pm	--	30	ND
	3/29-am	--	40	ND
	3/30-am	ND	ND	ND
	3/30-pm	ND	20	ND
	3/31-am	ND	ND	ND

ND - not detectable
x - radioiodine present
-- - sample not collected

in Figure 7. The ^{131}I level was observed to decay with a half-life of 4.5 days, close to the 5 day value assumed by the Federal Radiation Council.

6. Vegetation Sampling

Vegetation samples were taken on Highway 95 north and southeast of Beatty to determine a hot line and cloud profile at that distance. As seen in Figure 8, the peak occurred at 10 miles SE of Beatty, or 24 miles at 260° from Test Cell A.

Vegetation samples, containing fresh fission products, other than the samples previously mentioned (milk results and Highway 95), were also obtained at Barstow, Independence (Loden Ranch), Olancha (Hayhorst Ranch), and Stovepipe Wells, California. Milk samples were not available from Stovepipe Wells, but milk from the other locations did not show the presence of fresh fission products because the cows were not on fresh feed.

7. Thyroid In Vivo Counting

Thyroid in vivo counting was performed on two ground monitors who were located on Highway 95 during cloud passage. In both cases the thyroid doses were negligible.

8. Water

Water samples containing fresh fission products were obtained from Lone Pine and Olancha, California. The results are given in Table 13. The water was not used for human consumption.

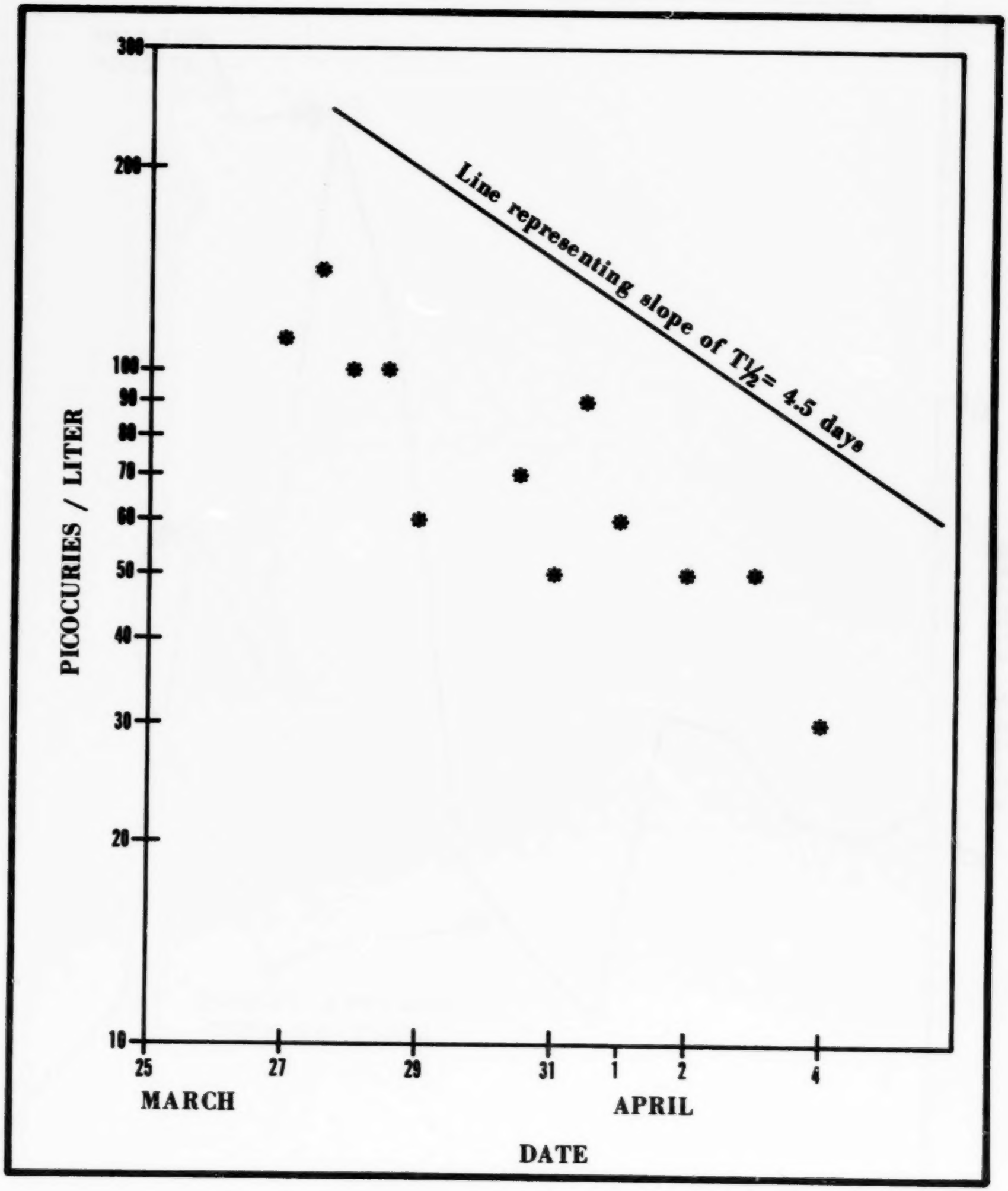

Figure 7. **IODINE-131 IN MILK, LONE PINE, CALIFORNIA FOLLOWING NRX-A4/EST, 3/25/66, EP-4A.**

Figure 8

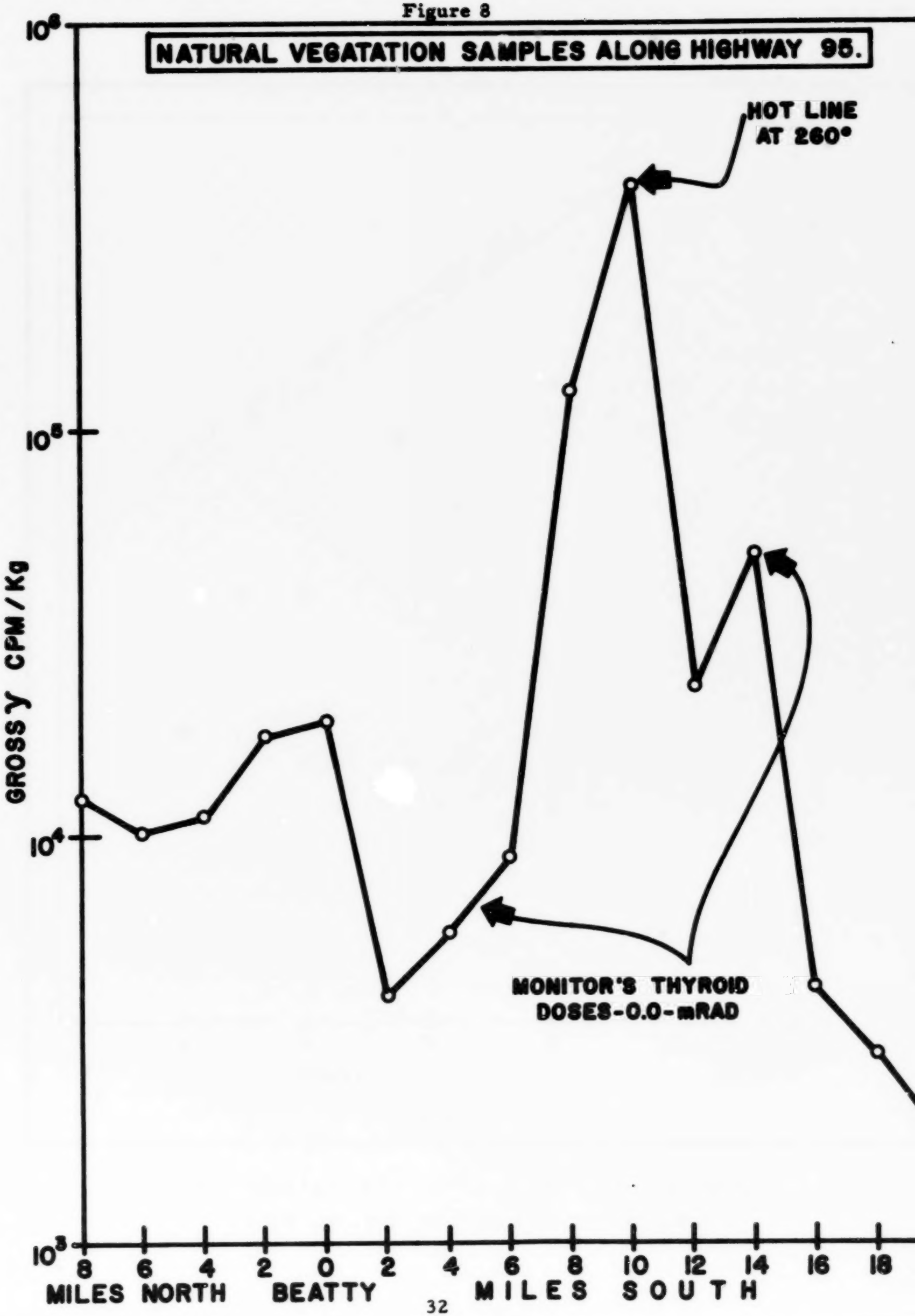
NATURAL VEGATATION SAMPLES ALONG HIGHWAY 95.
HOT LINE AT 260°
MONITOR'S THYROID DOSES-0.0-mRAD
GROSS γ CPM / Kg
10⁶
10⁵
10⁴
10³
8 6 4 2 0 2 4 6 8 10 12 14 16 18
MILES NORTH BEATTY MILES SOUTH

Table 13. Water Results--NRX-A4/EST EP-4A

Location	Date	pCi/liter ^{131}I	^{132}I
Lone Pine, Calif. Lone Pine Dairy	3-27	620	ND
Lone Pine, Calif. 1 mi south	3-28	750	70
Olancha, Calif. Hayhorst Ranch	3-28	110	ND

CONCLUSIONS

The effluent from four of the tests in the NRX-A4/EST series was detected off-site. The potential population doses were insignificant compared to the AEC Standards.

The AEC radiation protection standards for the average dose to a suitable sample of population are[1]:

whole body radiation - 170 millirem/year

thyroid exposures - 500 millirem/year

The peak external gamma doses detected off-site from the various tests are given in Table 14.

Table 14. Peak gamma doses detected off the test range complex for NRX-A4/EST. (Populated locations noted)

Test	Location	Dose or dose rate
EP-2B		not detectable
EP-2C		not detectable
EP-3	Hwy. 95, 17 mi SE of Lathrop Wells	< 0.01 mR/hr
EP-4	Hwy. 93 between Glendale & Alamo	< 0.03 mR/hr
EP-4A	Beatty, Nevada (populated)	< 0.1 mR
EP-4A	14 mi SE of Beatty on Hwy. 95	17 mR

Table 15 gives the peak radioiodine levels as measured from the air samplers (prefilter and charcoal cartridge). Fresh fission products were detected off-site following all tests except EP-2C.

(1) U.S. Atomic Energy Commission Manual Chapter 0524, Standards for Radiation Protection.

Table 15. Peak iodine concentrations as measured by air samplers.

Test	Location	Col-lec-tor	Iodine concentration in pCi/m³ (End of collection)				Collection Time(hrs)
			^{131}I	^{132}I	^{133}I	^{135}I	
EP-2B	Hiko, Nevada	P	ND	ND	0.18	ND	19.7
		C	ND	ND	ND	ND	
EP-3	Jct. Ash Meadows Road and U S 95, Nevada	P	ND	ND	2.2	ND	18.5
		C	ND	ND	2.0	ND	
EP-4	Butler Ranch turnoff and U S 93, Nevada	P	25	75	24	ND	2.2
		C	ND	ND	6.1	7.9	
EP-4A	Lone Pine, Calif.	P	61	ND	70	ND	23.8
		C	25	12	74	ND	

ND - not detectable
P - prefilter
C - charcoal cartridge

Assuming a person were present at the location where the iodine concentrations in Table 15 were measured, the potential thyroid exposure from inhalation of radioiodine can be estimated (Appendix 1). These estimates are given in Table 16. It was assumed that the iodine from both the filter and charcoal cartridge was biologically available to the thyroid.

Table 16. Estimates of thyroid exposures from peak radioiodine air concentrations.

Test	Location	Dose to thyroid in millirad(2)		Total
		^{131}I*	^{133}I**	
EP-2B	Hiko, Nevada	ND	<0.1	<0.1
EP-3	Jct. Ash Meadows Rd. and US 95, Nevada	ND	<0.1	<0.1
EP-4	Butler Ranch turnoff and US 93, Nevada	<0.1	<0.1	<0.1
EP-4A	Lone Pine, Calif.	2.52	1.14	3.7

(2) Based on ICRP "Standard Man", Publication 2(1959)
* Conversion factor for ^{131}I dose $\frac{3.42 \times 10^{-7} \text{ millirad}}{\text{pCi-sec/m}^3}$
** Conversion factor for ^{133}I dose $\frac{9.21 \times 10^{-8} \text{ millirad}}{\text{pCi-sec/m}^3}$

The potential exposures in Table 16 are less than 1% of the AEC standard for the thyroid exposure to a suitable sample of the population(500 millirem per year).

Radioiodine was not detected in milk except for the EP-4A test (cows were not on fresh feed or green chop for the EP-4 test). The peak milk concentration for the EP-4A test occurred in Lone Pine, California (140 pCi/liter of ^{131}I and 230 pCi/liter of ^{133}I). The half-life in milk was observed to be about 4.5 days or about that assumed by the Federal Radiation Council.[3] From data given in FRC No. 5[3] page 14, it is estimated that the thyroid dose to a child with a 2 gram thyroid would be 22 millirem(mrem) due to ^{131}I ingestion.

The parameters for the FRC dose model for ^{131}I in milk[3] are generally based on average values. A refinement of the ^{131}I calculation, based on specific information from the samples at Lone Pine, indicates a potential dose around 16 mrad from the ^{131}I (peak occurred earlier than in FRC model and effective half-life of ^{131}I in milk was about 4.5 versus 5 days). It should be noted that the estimated half-life was based on limited data, but it appears that the potential dose was less than that based on the FRC assumptions.

An additional 3 millirem exposure could have resulted from ingestion of ^{133}I in milk, resulting in a total exposure about 19 mrem(based on parameters from event). Assuming the inhalation dose to a child is about three times that of an adult*, the inhalation dose would be about 11 mrem(from Table 16). Thus an estimate of the total potential dose would be 30 mrem or about 6% of the AEC standard for a suitable sample of the population. Using the FRC assumptions the potential dose would have been about 7% of the AEC standard.

(3) Background Material for the Development of Radiation Protection Standards, Federal Radiation Council Report No. 5, July 1964.

* Based on child with 2 gram thyroid breathing 6 m^3/day and other parameters equivalent to those of ICRP(Appendix 1).

Appendix I

Thyroid Dose

$$\frac{\text{Thyroid Dose (D) rads}}{\frac{\text{curie-second}}{\text{meter}^3}} = f_a \times 3.7 \times 10^{10} \frac{\text{dis}}{\text{sec-curie}} \times 8.64 \times 10^4 \frac{\text{secs}}{\text{day}}$$

$$\times E \times 1.6 \times 10^{-6} \frac{\text{ergs}}{\text{mev}} \times B \times \frac{1}{M} \times \frac{1}{100} \frac{\text{ergs}}{\text{gram}} \times \int_0^{\infty} e^{-\frac{.693t}{Te}} dt$$

fa = fraction of inhaled iodine that reaches thyroid = .23

E = energy to thyroid/disintegration = .23 mev ^{131}I

E = energy to thyroid/disintegration = .54 mev ^{133}I

B = breathing rate = 2.32×10^{-4} m^3/second

$\frac{1}{m}$ = mass of thyroid $^{-1}$ = $\frac{1}{20}$ grams

Te = effective half-life = 7.6 days ^{131}I

Te = effective half-life = .87 days ^{133}I

$$\frac{\text{Rad}}{\frac{\text{curie-sec}}{M^3}} = 1.97 \times 10^2 \times E \times Te$$

$$\frac{\text{Rad}}{\frac{\text{curie-sec}}{M^3}} = \frac{3.42 \times 10^{-7} \text{ millirad}}{\text{pCi-sec}/M^3} \qquad (^{131}I)$$

$$\frac{\text{Rad}}{\frac{\text{curie-sec}}{M^3}} = \frac{9.21 \times 10^{-8} \text{ millirad}}{\text{pCi-sec}/M^3} \qquad (^{133}I)$$

DISTRIBUTION

1 - 15	SWRHL, Las Vegas, Nevada
16	James E. Reeves, Manager, NVOO/AEC, Las Vegas, Nevada
17	Robert H. Thalgott, NVOO/AEC, Las Vegas, Nevada
18	Henry G. Vermillion, NVOO/AEC, Las Vegas, Nevada
19	D. H. Edwards, Safety Evaluation, NVOO/AEC, Las Vegas, Nev.
20	D. W. Hendricks, Rad. Safe. Br., NVOO/AEC, Las Vegas, Nev.
21	Central Mail & Records, NVOO/AEC, Las Vegas, Nevada
22	A. J. Whitman, NTSSO, NVOO/AEC, Mercury, Nevada
23 - 24	R. Decker, SNPO, Washington, D. C.
25	D. Smith, SNPO-C, Cleveland, Ohio
26 - 27	J. P. Jewett, SNPO-N, Jackass Flats, Nevada
28 - 31	R. Nelson, SNPO-N, NRDS, Jackass Flats, Nevada
32	William C. King, LRL, Mercury, Nevada
33	Roger Batzel, LRL, Livermore, California
34	H. L. Reynolds, LRL, Livermore, California
35 - 36	H. T. Knight, LASL, Jackass Flats, Nevada
37	P. Gothels, LASL, Los Alamos, New Mexico
38	H. S. Jordan, LASL, Los Alamos, New Mexico
39	Charles I. Browne, LASL, Los Alamos, New Mexico
40	William E. Ogle, LASL, Los Alamos, New Mexico
41	H. G. Simens, NTO, Aerojet-General Corp., Jackass Flats, Nev.
42	G. Grandy, WANL, NRDS, Jackass Flats, Nevada
43 - 44	E. Hemmerle, WANL, Pittsburgh, Pennsylvania
45 - 46	S. Z. Mikhail, NRDL, San Francisco, California
47 - 48	M. I. Goldman, NUS, Washington, D. C.
49 - 50	J. Mohrbacher, Pan Am. World Airways, Jackass Flats, Nev.
51	P. Allen, ARL, ESSA, Las Vegas, Nevada

52 H. Booth, ARL, ESSA, Las Vegas, Nevada

53 C. Anderson, EG&G, Las Vegas, Nevada

54 Byron Murphey, Sandia Corporation, Albuquerque, New Mexico

55 Brig. Gen. Edward B. Giller, DMA, USAEC, Washington, D. C.

56 - 57 Chief, NOB/DASA, NVOO/AEC, Las Vegas, Nevada

58 - 62 Charles L. Weaver, USPHS, NCRH, Rockville, Md.

63 Victor M. Milligan, REECo, Mercury, Nevada

64 Nevada Southern University, Library, Las Vegas, Nevada

65 - 66 DTIE, USAEC, Oak Ridge, Tennessee